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(54) Liquid ink printer for producing high resolution images

Flüssige Tinte verwendender Drucker für die Erzeugung von hochauflösendem Bilddruck

Imprimante à encre liquide pour produire des images à haute résolution

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(73) Proprietor: **XEROX CORPORATION**
Rochester, New York 14644 (US)

(72) Inventors:
- **Mantell, David A.**
  Rochester, NY 146109 (US)
- **O'Neill, James F.**
  Penfield, NY 14526 (US)
- **Tellier, Thomas A.**
  Wolcott, NY 14590 (US)
- **Deshpande, Narayan V.**
  Penfield, NY 14526 (US)
- **Kneezel, Gary A.**
  Webster, NY 14580 (US)
- **Torpey, Peter A.**
  Webster, NY 14580 (US)
- **Harrington, Steven J.**
  Holley, NY 14470 (US)

(74) Representative: **Grünecker, Kinkeldey, Stockmair & Schwanhäusser Anwaltssozietät**
Maximilianstrasse 58
80538 München (DE)

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- **PATENT ABSTRACTS OF JAPAN vol. 011, no. 105 (M-577), 3 April 1987 & JP 61 254350 A (MITSUBISHI ELECTRIC CORP), 12 November 1986,**

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Description

[0001] The present invention relates generally to a liquid ink printing apparatus, and more particularly to an ink jet printer for producing high resolution images.

[0002] Printers typically print information received from an image output device such as a personal computer. Typically, this received information is in the form of a raster scan image such as a full page bitmap or in the form of an image written in a page description language. The raster scan image includes a series of scan lines consisting of bits representing pixel information in which each scan line contains information sufficient to print a single line of information across a page in a linear fashion. Printers can print bitmap information as received or can print an image written in the page description language once converted to a bitmap consisting of pixel information.

[0003] Bitmaps printed by a printer can be printed at the resolution of the received bitmap. The printer can also modify the received bitmap and print the information at a resolution different than the one received. In either event, it is generally believed, under most circumstances, that the higher the resolution of the printed image, or the higher the perceived resolution of the printed image, the better that image will be received by one viewing the image. Consequently, most printer manufacturers strive to print higher resolution images by either producing printheads having more ink ejecting nozzles per inch or by artificially creating the appearance of higher resolution images with printing algorithms which manipulate or alter the received bitmap.

[0004] In US-A-4,714,934 to Rogers, an impulse inkjet apparatus capable of printing bar codes having a plurality of side-by-side chambers extending along a line slanted with respect to the direction of scanning is described. Each of the chambers includes a plurality of orifices arranged along a line extending substantially transverse to the scanning direction. Droplets are simultaneously ejected from a plurality of orifices by energizing a single transducer, such that bar code and alphanumeric printing is achieved.

[0005] US-A-4,901,093 to Ruggiero et al, describes an impulse ink-jet apparatus providing bar codes using one or more ink-jet chambers having a plurality of orifices in each chamber. A transducer is coupled to each chamber for ejecting droplets from each of the plurality of orifices in the chamber in response to the state of energization of the transducer.

[0006] US-A-5,258,774 to Rogers, describes an impulse ink-jet apparatus having a plurality of side-by-side chambers extending along a line that is slanted with respect to a scanning direction relative to a recording medium. Each of the chambers includes a plurality of orifices that are arranged along a line extending substantially transverse to the scanning direction and a transducer for ejecting a plurality of droplets from the orifices of each chamber.

[0007] US-A-5,270,728, to Lund et al., describes a method for multiplying the speed-resolution product of a raster scanning or imaging device such as an ink jet printer, and a resulting data structure. A 300 dots per inch (dpi) by 600 dpi logical pixel image is mapped to a corresponding, non-overlapping physical dot image. The printer's ink jets are fired responsive to the dot image to direct individual generally spherical ink droplets onto paper at 600 dpi resolution grid timing in order to effectively double the horizontal resolution of the printed pixel image. Documents EP-A-627 314 and US-A-4 905 017 show printers for depositing liquid ink on a recording medium comprising a printhead with a plurality of nozzles and a plurality of transducers having centers spaced a distance apart, each of said plurality of transtucers being cooperatively associated with at least two of said plurality of nozzles.

[0008] In accordance with one aspect of the present invention, there is provided a printing machine comprising the features as defined in claim 1.

[0009] Pursuant to another aspect of the present invention, there is provided a method of printing high resolution images on a recording medium as defined in claim 9.

[0010] The present invention will now be described, by way of example, with reference to the accompanying drawings, in which:

FIG 1 is a partial schematic perspective view of an ink jet printer incorporating the present invention;
FIG. 2 illustrates the locations of ink drops deposited by a printhead in a 1 by 1 pattern;
FIG. 3 illustrates the locations of ink drops deposited by a printhead in a 1 by 2 pattern;
FIG 4 is a schematic perspective view of an ink jet print cartridge having an ink jet printhead with ink ejecting nozzles and associated heaters therefore incorporating the present invention;
FIG. 5 illustrates the locations of ink drops deposited by the printer of the present invention;
FIG. 6 is a partial schematic side view of the printhead illustrated in FIG. 4 along the line 6-6;
FIG. 7 is a partial schematic plan view of the printhead illustrated in FIG. 4 along the the line 7-7;
FIG. 8 is a partial schematic plan view of another embodiment of the printhead of the present invention.;
FIG. 9 is a partial schematic plan view of another embodiment of the printhead of the present invention;
FIG. 10 is a partial schematic elevation view of the nozzles of the present invention;
FIG. 11 illustrates the locations of ink drops deposited by a printhead printing a two pass, 1 by 1 pattern;
FIG. 12 illustrates the locations of ink drops deposited by a printhead of the present invention printing a two-pass, 1 by 2 pattern;

FIG. 13 illustrates the locations of ink drops deposited by a printhead printing a 1 by 4 pattern;

FIG. 14 illustrates the locations of ink drops deposited by a printhead having an orifice plate having a staggered array of nozzles.

[0011] FIG. 1 illustrates a partial schematic perspective view of an ink jet printer 10 having an ink jet printhead cartridge 12 mounted on a carriage 14 supported by carriage rails 16. The printhead cartridge 12 includes a housing 18 containing ink for supply to a thermal ink jet printhead 20 which selectively expels droplets of ink under control of electrical signals received from a controller 21 of the printer 10 through an electrical cable 22. The printhead 20 contains a plurality of ink conduits or channels (not shown) which carry ink from the housing 18 to respective ink ejectors, which eject ink through orifices or nozzles (also not shown). When printing, the carriage 14 reciprocates or scans back and forth along the carriage rails 16 in the directions of the arrow 24. As the printhead cartridge 12 reciprocates back and forth across a recording medium 26, such as a sheet of paper or transparency, droplets of ink are expelled from selected ones of the printhead nozzles towards the sheet of paper 26. The ink ejecting orifices or nozzles are typically arranged in a linear array substantially perpendicular to the scanning direction 24. During each pass of the carriage 14, the recording medium 26 is held in a stationary position. At the end of each pass, however, the recording medium is stepped by a stepping mechanism under control of the printer controller 21 in the direction of an arrow 28. For a more detailed explanation of the printhead and printing thereby, refer to U.S. Patent No. 4,571,599 and U.S. Patent No. Reissue 32,572.

[0012] It is well known to program and execute imaging, printing, document, and/or paper handling control functions and logic with software instructions for conventional or general purpose microprocessors. This is taught by various prior patents and commercial products. Such programing or software may, of course, vary depending on the particular functions, software type, and microprocessor or other computer system utilized, but will be available for use with, or readily programmable without undue experimentation from, functional descriptions, such as those provided herein. That can include object oriented software development environments, such as C++. Alternatively, the disclosed system or method may be implemented partially or fully in hardware, using standard logic circuits or a single chip using VLSI designs.

[0013] The carriage 14 is moved back and forth in the scanning directions 24 by a toothed belt 38 attached thereto. The belt 38 is driven by a first rotatable pulley 40 and a second rotatable pulley 42. The first rotatable pulley 40 is driven by a reversible motor 44 under control of the controller 21 of the ink jet printer. In addition to the toothed belt/pulley system for causing the carriage to move, it is also possible to control the motion of the carriage by using a cable/capstan, lead screw or other mechanisms as known by those skilled in the art.

[0014] To control the movement and/or position of the carriage 14 along the carriage rails 16, the printer includes an encoder having an encoder strip 46 which includes a series of fiducial marks in a pattern 48. The pattern 48 is sensed by a sensor 50, such as a photodiode/light source attached to the printhead carriage 14. The sensor 50 includes a cable 52 which transmits electrical signals representing the sensed fiducial marks of the pattern 48 to the printer controller.

[0015] FIG. 2 illustrates the locations of ink drops deposited by a printhead in a 1x1 pattern, as known in the art. In such a printhead, for instance printing at 118 spots/cm (300 spots per inch), the pixels are placed on a square grid having a size S where S is generally the spacing between the marking transducers 59 or channels (not shown) on the printhead as schematically illustrated. The nozzles 60, schematically represented as triangles, each associated with a single transducer 59, traverse across a recording medium in a scan direction X as illustrated. Other nozzle shapes are also possible such as those formed by isotropic etching, having rounded features, or by plasma etching, having angular or trapezoidal features. The nozzles, which are spaced from one another a specified distance S, also known as the pitch, deposit ink spots 62 on a grid, wherein the ink spots have pixel centers 64 spaced a distance S apart. The ink nozzles 60 are designed to produce spot diameters of approximately 1.414 (the square root of 2) times the grid spacing S, which is here illustrated as the distance D. This distance provides complete filling of space by enabling diagonally adjacent pixels to touch. Consequently, in 1x1 printing (e.g., 300 x 300), the spots need to be at least 1.41S to cover the paper. In practice however, the ink spots or pixels may be made slightly larger to ensure full coverage of the paper.

[0016] FIG. 3 illustrates the locations of ink drops deposited by a printhead in a 1x2 pattern, wherein the printhead includes a plurality of nozzles 66 having the same pitch S as the schematically represented printhead illustrated in FIG. 2. In FIG. 3, however, the printhead is printing at 300 x 600 pixels addressability, meaning that the nozzle spacing is 118 spots/cm (300 spots per inch) in the Y direction, but 236 spots/cm (600 spots per inch) in the X direction or scanning direction of the carriage. To print at 236 spots/cm (600 spots per inch) in the scanning direction, the distance between pixel centers 68 of the individual ink drops 70 is S divided by 2. When printing at 236 spots/cm (600 spots per inch) in the scanning direction or, more generally, at twice the resolution of the printhead addressability, the spot size can be reduced to 1.12S. This particular drop size requires two drops, each of which produce a little over one-half of the ink of the larger 1x1 spot area as illustrated in FIG. 2. The relationship of drop size to printing schemes is as follows:

$$1x1: 1.41^2 = 2;$$

$$1x2: 2 \times (1.12^2) = 2.5$$

[0017] Assuming a constant thickness model for the translation from drop volume to spot size in 1x2 addressability printing, full coverage would require 25% more ink than in 1x1 addressability printing. The exact relationship, of course, depends on the specific ink and paper or transparency being covered.

[0018] Certain trade-offs are made when increasing the printing resolution of a liquid ink printer, since printing throughput is proportional to the carriage velocity, V, relative to the recording medium and to the active printing length, L, of the printhead, where the printing length L equals NxS where N is the total number of channels on the printhead. The carriage velocity V is equal to FxQ, where F is the nozzle firing frequency and Q is the distance between printed pixels along the scanning direction. The maximum frequency may be limited by how quickly the ink carrying channels can refill with ink, or by how quickly the full set of N channels may be fired. For example, if M is equal to 4, wherein M is equal to the number of channels fired simultaneously, having a firing pulse width of T=3 microseconds and a dead time between pulses of .25 microseconds, then the frequency will have an upper limit of 4/(3.25xN). Consequently, in order to preserve printing throughput when resolution is increased (i.e., when S or Q are made smaller), then N and/or F must be made larger. If the upper limit to F is due to the time to ripple through the nozzles firing, then either M must be increased or T must be decreased. Producing smaller drops is synergistic with faster operation. Shorter (higher voltage) pulses produce smaller drops and less ink per drop leads to faster channel refill. Alternately, smaller heaters can be used when producing smaller drops, so more heaters can be fired simultaneously.

[0019] As the distance between adjacent drop centers in the scanning direction decreases, typically the channel width, W (see FIG. 2), also decreases. While higher resolution printheads tend to have a lower printing throughput because more dots are to be printed, the faster refill time helps to minimize the slowdown. Consequently, while printing a 1x2 print scheme may take longer than the printing of a 1x1 print scheme, the smaller and more numerous drops of the 1x2 print scheme will improve image quality in three additional ways. One, smaller spots allow smaller features to be adequately resolved. Two, smaller spots improve the quality of the gray scale that can be produced. This occurs because in a halftone, both the lightest level that can be printed and the fineness of the gray levels that can be distinguished are controlled by the smallest spot that can be printed. Three, the large pixel overlap of adjacent drops one-half pixel spacing apart can also improve the number of gray levels.

[0020] While a printer printing an actual 1x2 print scheme includes the above-mentioned advantages and disadvantages, such a printer could also require an additional 25% ink usage when compared to 1x1 printing. However, the printer of the present invention which includes the printhead cartridge 12, as illustrated in FIG. 4, cleverly regains the additional ink required by placing two nozzles over a single heater to produce two small drops simultaneously. The printhead cartridge 12, therefore, includes the printhead 20 having a plurality of nozzles 74, wherein two of the nozzles are placed in cooperative association with a single heater 76. The single heater 76 vaporizes the ink which is located adjacent to the heater, and consequently upon vaporization thereof, ink is expelled from two of the nozzles 74 simultaneously.

[0021] The ink jet printhead 20, or a printhead die, includes a transducer element 77,or a heater die, including resistive heaters, and an ink directing element 78, or a channel die. The channel die includes an array of ink conduits or fluidic channels which bring ink into thermal contact with the transducers which are correspondingly arranged on the heater die. Channel dies can be made of silicon, glass, plastic, or other known materials in which ink carrying conduits can be formed. In addition, the printhead die may also have integrated addressing electronics and driver transistors.

[0022] Fabrication yields of die assemblies at a resolution on the order of 118-236 channels/cm (300-600 channels per inch) is such that the number of channels per die is preferably in the range of 50-600 under current technological capabilities. Because thermal ink jet nozzles typically produce spots or dots of a single size, high quality printing requires the fluidic channels and corresponding heaters to be fabricated at a high resolution on the order of 118-472 channels/cm (300-1200 channels per inch).

[0023] In an orientation dependent etching method of channel fabrication on silicon wafers, the channels are triangular shaped with a height equal to 0.707 times the channel width. For orientation dependent etching of silicon, a standard channel width for 118 spots/cm (300 spots per inch) printing is approximately sixty-six µm and for 236 spots/cm (600 spots per inch) printing is twenty-five µm.

[0024] As illustrated in FIG. 5, a plurality of ink drops 80 having pixel centers 82, deposited by the printhead of FIG. 4, is illustrated. Since every two nozzles eject ink under the control of a single heater 76, having centers spaced a distance, S, apart, the printing scheme is not a true 1x2 but is instead a (1/2x2) x 2 print scheme, also referred to herein as "apparent 1x2 printing". While the transducer spacing is S, the spacing betweeen adjacent drops in the X or scanning direction, which is controlled by the controller 21, is selected as a function of S divided by the number of nozzles simultaneously ejecting ink under control of a single transducer. If FIG.

2 represents 118x118 spots/cm (300x300 spi), then FIG. 5 has the appearance of solid area coverage at 236x236 spots/cm (600x600 spi). In fact, however, this new configuration is more like 118x236 spots/cm (300x600 spi), but with an oblong spot (formed by the simultaneous ejection through a pair of nozzles which is optimized for low ink usage and gray scale.

[0025] As shown in FIG. 5, the pitch P has been chosen such that two 236 spots/cm (600 spots per inch) drops are placed on standard 236 spots/cm (600 spots per inch) spacings in the Y direction. If the nozzle size is 25 micrometers, the spacing between nozzles is approximately 17.5 micrometers. This spacing requires a distance from the first edge of one nozzle in a pair of nozzles to the opposite edge of the second nozzle to be 67.5 micrometers. As another example, if the nozzle size is 30 micrometers, the spacing between adjacent nozzles would be 12.5 micrometers and the spacing between opposite edges, would be equivalent to 72.5 micrometers. In this instance, the total ink usage for full coverage could be:

$$(1/2x2) \times 2: 2x(2x.71^2)=2$$

[0026] This amount is comparable to the ink usage for 1x1 printing. It has been found, that the overall area of the (1/2x2) x 2 pixel is even smaller than the true 1x2 pixel. Consequently, the lightest gray level that can be printed is further improved for the (1/2x2)x2 design. In addition, the advantages of a distributed ink flow still apply and therefore a significant throughput advantage for a printer configured to print in (1/2x2) x 2 addressability may be possible. Furthermore there is an advantage in the number of heaters which can be fired simultaneously, in printheads printing a single line of pixels in a burst of several banks of nozzles, wherein each bank prints a segment of a line. In these types of printheads, the banks of nozzles are typically fired sequentially and the nozzles within a bank are fired simultaneously. Refer to US-A-5,300,968. In such a printhead, for true 236x236 spots/cm (600x600 spots per inch) printing with 256 nozzles per printhead die, eight individual heaters are fired simultaneously in order to ripple through all 256 nozzles (at a 3.25 microsecond pulse separation) in order to achieve a firing frequency of 6 kilohertz. For the present invention, however, since there are only 128 heaters for 256 channels, only four heaters need to be fired at once. Fewer heaters fired simultaneously is preferable since the less heaters fired at a time reduces the voltage drops in the heater die due to parasitic resistances within a printhead. In addition, the heaters could also be made smaller since the amount of ink ejected per nozzle is less.

[0027] FIG. 6 illustrates a partial schematic side view of the printhead 20 along the line 6-6 of FIG. 4. The printhead element 20 includes the ink directing element 78 mated and aligned to the transducer element 77. The printhead element 20 receives ink from a supply of ink (not shown) through an ink feed slot 94 defined in the ink directing element 78. Ink passes through the ink feed slot 94 into an ink reservoir 96 which contains an amount of ink which eventually flows therefrom in the direction of an arrow 97 through an ink pit 98, through a channel 100, and out through one of the plurality of nozzles 74 defined by the mated ink directing element 78 and transducer element 77. During printing, a heater 76 located beneath a heater pit 106, also filled with ink, begins to vaporize the ink above the heater 76. A pit wall 107 separates the heater pit 106 from the ink pit 98. A vapor bubble is created which ejects a certain amount of ink from the nozzle 74. Once the ink is ejected from the channel 100, ink again flows in the direction of the arrow 97 by capillary action to refill the channel 100 and the heater pit 106 for subsequent ejection of ink.

[0028] FIG. 7 illustrates a partial schematic plan view of one embodiment of the present invention along the line 7-7 of FIG. 4. Two of the ink channels 100, also known as ink carrying conduits, terminate in the nozzles 74. Each pair of ink carrying conduits 100 is respectively located adjacently to one of the heater pits 106. The ink reservoir 96, as previously described, holds ink for its eventual discharge through the nozzles. The single heater 76 vaporizes the ink present in adjacently located channels 100A and 100B. While the heater pits, and consequently the individual heaters are spaced at a first pitch, the channels are spaced at a pitch which is half that of the heater pitch spacing or at a frequency that is twice the spacing. In this particular embodiment, the channels extend to the bypass pit 98 to thereby allow ink flow between the ink reservoir 96 and the respective channels. Such a configuration is possible for a spacing of 236 spots/cm (600 spots per inch) between adjacent nozzles under the current available techniques of etching silicon wafers. It is also possible, however, that future designs can have nozzle spacings of 472 spots/cm (1200 spots per inch) or greater with heater spacings of one-half that amount.

[0029] FIG. 8 illustrates a partial schematic plan view of another embodiment of the printhead of the present invention. In FIG. 8, however, a plurality of channels or ink carrying conduits 104 are of a standard channel width, for example, for 118 spots/cm (300 spots per inch) printing. In such a configuration, each of the channels 104 is located directly adjacent to one of the heater pits 106 and its associated heater. This embodiment, however, differs, from the example of FIG. 7, in that the single channel 104 is divided into the first and second nozzles 74A and 74B, by a branched portion having a first branch 107A and a second branch 107B which is forked by a timed ODE etch to produce two small nozzles at the jetting end. As was previously described for FIG. 7, the embodiment of FIG. 8 includes a single heater element per every two nozzles but differs in that this particular configuration has a single heater element for every single channel.

[0030] FIG. 9 illustrates a third alternate embodiment of the present invention which does not include a pit wall separating a heater pit from an ink pit, as previously shown in FIG. 6. Consequently, the FIG. 9 embodiment includes a single bypass pit 110 which allows ink flow directly from the ink reservoir 96 to the heater element. A plurality of individual channels 112 spaced at, for example, 236 spots/cm (600 spots per inch) are operatively connected to a connecting channel 114 by the bypass pit 110. Such a configuration might be optimized so that jetting parameters such as drop velocity, drop volume, and refill frequency are optimized for the particular ink being used and the required range of printing conditions.

[0031] FIG. 10 illustrates a schematic front view of the individual nozzles, formed by etching channels in silicon, of the present invention with respect to the nozzle openings of a printhead having printhead nozzles spaced at 118 spots/cm (300 spots per inch). A spacing distance of A is approximately 17 micrometers while the width of the channels, B, is 25 micrometers. 118 spots/cm (300 spots per inch) channel nozzles 116 are shown in dotted outline to illustrate the respective size of the larger and the smaller nozzle openings. FIG. 10 may also be understood to represent the front view of the FIG. 8 embodiment where the dotted line represents the channel 104 coupled to two nozzles 74.

[0032] Because the described embodiments typically fire banks of heaters sequentially to eject ink throughout the linear array of nozzles, the printhead must be slightly tilted with respect to the scanning direction. In order to stitch together printhead passes correctly, the tilt of the printhead for 1x2 printing must be one-half pixel. While it is possible to print images by tilting the printhead at one-half pixel, firing banks of nozzles sequentially has inherent difficulties when printing full coverage. For instance, interactions in the ink being ejected from the nozzles limits the frequency that the device can be operated. Additionally, for some ink formulations overlapping the individual ink drops from adjacent pixels fired together does not leave sufficient time for drying, leading to increased paper curl and bleeding. Possible solutions include ejecting ink from alternate nozzles simultaneously. Firing the alternate nozzles simultaneously may not necessarily solve the problem of ink flow interactions, however. Another possible solution is to change the order in which banks of nozzles are fired with a corresponding change to the tilt of the printhead.

[0033] One possibility is to eject ink from a first bank of nozzles at the topmost portion of the printhead followed by ejecting ink from a second bank of nozzles located just past one-half way down the printhead by tilting the printhead by one pixel instead of one-half pixel. Spots deposited by the second bank are automatically displaced one-half pixel from spots deposited by the first bank. After these two banks eject ink, the second bank from the top half of the printhead array ejects ink followed by the second bank from the bottom half of the printhead array ejecting ink. Thereafter, alternating banks from the top half and the bottom half of the printhead eject ink. Tilting the printhead a larger amount permits a greater distribution of the firing pattern. Other modes are also possible where widely separated nozzles are fired simultaneously. For example, in printhead having 256 nozzles, every 32nd nozzle is fired such that nozzle 1, 33, 65, 97, 129, 161, 193, and 225 are fired initially. In the second print cycle nozzles 2, 34, 66, 98, 130, 162, 194, and 226 are fired. For such a print scheme, the printhead tilt should be four pixels. Then with nozzle 1 centered on a 1x2 pixel position, nozzle 33 will be displaced by one-half pixel therefrom, nozzle 65 by one pixel, nozzle 97 by one and one-half pixel, and so on to where nozzle 226 is tilted by three and one-half pixels. Thus, all the pixels automatically line up on a 1x2 grid. Such a mode of printing has the optimum distribution of ink flow throughout the system.

[0034] In addition, it is possible to print images in two passes of the printhead as opposed to one. Certain advantages of a two pass print scheme include allowing the ink to dry between passes, simultaneously firing alternate nozzles, masking printhead signatures by printing adjacent spots with different portions of the printhead, and printing single pass ink-saving draft print modes. In each pass, odd and even pixels are placed on centers separated by one-half pixel in the scanning direction by firing the odd nozzles and the even nozzles separately and controlling the order in which they are fired. For instance, in a first pass, wherein eight nozzles can be fired simultaneously, banks of odd nozzles, for instance, 1, 3, 5, and so on, are fired starting at the top of the printhead and then the second bank of odd nozzles 17, 19 on up to 31 progressing to the bottom. Printing in this scheme completes in half the print cycle time for all of the odd fired nozzles. Once the odd nozzles are printed, then the even nozzles are fired, starting at the top of the printhead 2, 4 on up to 16 and progressing to the bottom. If the printhead speed across the paper is one pixel per print cycle, then the odd nozzles will be placed on 1x1 pixel positions and the even nozzles will displaced by one-half pixel on the one-half pixel positions. On the second pass, the evens are fired first, followed by the odds. The evens will be on the 1x1 pixel positions and the odds on the 1x2 pixel positions. In order to maintain the correct placement of the drops, the printhead should be tilted one-half pixel.

[0035] FIG. 11 illustrates a two pass print scheme for a true 1x2 print scheme. A single pass 120 of the printhead illustrates that a relatively high ink coverage of the recording medium is possible with minimum pixel overlap therefore making a good ink conserving draft print mode. Once the second pass has been completed, a two pass print scheme 122 illustrates that full coverage has been achieved. As further illustrated in FIG. 12, the printhead of the present invention having two nozzles per transducer deposits ink drops by firing odd transducers on odd numbered columns and even numbered transducers in even numbered columns in a first pass

print 124 of the printhead. A second pass of the printhead deposits ink drops by firing even numbered transducers on odd numbered columns and odd numbered transducers on even number columns to provide full coverage printing 126. It also possible to print only the first pass 124 for draft mode printing.

[0036] While the present invention has been described with respect to two nozzles per heater, the present invention is not limited thereto, and can include any plurality of N nozzles per heater. For instance, as illustrated in FIG. 13, four individual nozzles 130 eject ink simultaneously under control of a single transducer 132 to print images having 1x4 addressability. Each bank of four separate nozzles produces a single drop, also known as a subpixel, when the heater is fired. The result is a tall, narrow pixel 134 which can be deposited one, two, three or four times in the area of a standard size single normal pixel 136. Consequently, the four nozzles per heater can achieve five different gray levels, including white, whereas in normal printing there are only two. Furthermore, the lightest gray level is less than one-quarter of the lightest level in the purely binary case. Another advantage is that the total ink usage is less than full black because the ink is already spread out on the paper, since a number of small drops are made to create one single large drop.

[0037] As illustrated in FIG. 14, it is not necessary that the drops be arranged in a straight line, particularly if an orifice plate 140 having a plurality of staggered apertures 142 is placed over the top of a single channel 144. The individual apertures in the aperture plate 140 are staggered about a line 146 by a distance S divided by 8. By staggering the nozzles and printing with a one pass print scheme, the ink needed for full coverage is reduced by approximately one-third.

[0038] Thus, there has been described a liquid ink printer printing images having increased resolution and additional levels of gray scale. While resolution is increased, the amount of ink necessary to print images according to the present invention is the same as that required for a lower resolution printer of the same type. It is, therefore, apparent that there has been provided in accordance with the present invention, an apparent 1xN liquid ink printer that fully satisfies the aims and advantages hereinbefore set forth. The present invention is not limited to scanning type liquid ink printers, but includes pagewidth printers as well which have a moving printbar.

[0039] Likewise, the present invention, is not limited to sideshooter type printheads, but also includes roofshooter type printheads. In addition, the present invention includes printheads having a variety of channel/nozzle configurations within a single printhead or within a printhead cartridge. For instance, a single printhead cartridge could include a first eight channels, each having one nozzle per channel, a second eight channels, each having two nozzles per channel and a third eight channels, each having four nozzles per channel. Such a printhead cartridge has a wider range of gray scale printing than printhead cartridges having only one type of channel/nozzle configuration.

Claims

1. A printing machine (10) in which liquid ink is deposited on a recording medium (26) to produce high resolution images thereon, comprising:

   a printhead (20) including a plurality of nozzles (74) and a plurality of transducers (76), the transducers having centers spaced a first distance, S, apart, each of said plurality of transducers cooperatively associated with at least two of said plurality of nozzles; and

   means (14,38,44) for moving said printhead across the recording medium to deposit liquid ink thereon at locations separated by a distance between adjacent droplets in a scanning direction of the printhead selected by a controller (21) as a function of the first distance, S, divided by the number of nozzles cooperatively associated with each of said plurality of transducers.

2. The printing machine of claim 1, wherein said printhead comprises a transducer element (77) including said plurality of transducers (76); wherein said printhead comprises an ink directing element (78) including said plurality of nozzles (74), said ink directing element aligned with and mated to said transducer element; wherein said plurality of nozzles comprises a linear array of nozzles; and wherein said means for moving comprises means for moving said linear array of nozzles across said recording medium in a direction (24) substantially transverse to said linear array of nozzles.

3. The printing machine of claim 2, wherein said ink directing element comprises a plurality of ink conduits (104), each of said ink conduits coupled to at least two of said spaced nozzles (74A,74B); and preferably wherein each of said ink conduits (104) comprise at least two branches (107A,107B), said at least two branches connecting one of said ink conduits (104) to at least two of said nozzles (74A, 74B).

4. The printing machine of claims 2 or 3, wherein said plurality of transducers comprises a linear array of thermal transducers (76), each of said thermal transducers generating thermal energy; and wherein said ink directing element comprises a silicon structure, said array of ink conduits and said branches defined by an etching process.

5. The printing machine of claim 2, wherein said ink directing element comprises a plurality of ink conduits (100A, 100B), each of said plurality of ink conduits coupled to one of said spaced nozzles (74A, 74B).

6. The printing machine of claims 3 to 5, wherein said ink directing element comprises a plurality of feed channels (94), each of said feed channels operatively coupled to at least one of said plurality of ink conduits (100A,100B,104); and wherein said transducer element (77) comprises a plurality of pit structures (98), each of said pit structures disposed adjacent to one of said feed channels and to at least one of said plurality of ink conduits (100A,100B, 104) for supplying ink to the nozzles.

7. The printing machine of claim 1, further comprising a controller (21) coupled to said moving means, controlling said moving means to enable said printhead to deposit ink drops at first locations and at second locations laterally spaced from the first locations a printing distance substantially equal to the distance between the centers of adjacent nozzles of said plurality of nozzles.

8. The printing machine of claim 1, wherein said plurality of nozzles comprises a staggered array of nozzles (142), each of said plurality of nozzles alternately located on opposite sides of a straight line (146).

9. A method of printing high resolution images on a recording medium (26) with a liquid ink printhead (20) having transducers (76) ejecting ink droplets on a recording medium, said transducers having centers spaced a distance, S, apart, each of said plurality of said transducers cooperatively associated with at least two of a plurality of nozzles comprising:

   depositing a first plurality of ink droplets (80) simultaneously by energizing a first transducer; and

   depositing a second plurality of ink droplets (80) simultaneously, spaced from adjacent ink droplets of the first plurality in a direction of scanning of the printhead by a distance selected as a function of the first distance, S, divided by the number of nozzles cooperatively associated with each of said plurality of said transducers.

10. The method of claim 9, wherein said second depositing step comprises depositing the second plurality of ink droplets simultaneously by energizing a second transducer; and wherein said first depositing step comprises depositing the first plurality of ink droplets with a scanning printhead including an ink directing element having a plurality of ink conduits coupled to an array of spaced nozzles and a transducer element having an array of transducers, the transducer element aligned with and mated to the ink directing element such that each of the transducers is substantially aligned with at least one of the plurality of ink conduits.

11. The method of claims 9 or 10, further comprising controlling the printhead to deposit the first plurality of ink droplets at first locations and to deposit the second plurality of ink drops at second locations spaced laterally from the first locations in the scanning direction a distance substantially equal to the distance between adjacent nozzles of the array of nozzles.

Patentansprüche

1. Druckervorrichtung (10), in der flüssige Tinte auf ein Aufzeichnungsmedium (26) zur Erzeugung hochauflösender Bilder darauf abgeschieden wird, mit:

   Einem Druckkopf (20) einschließlich mehreren Düsen (74) und mehreren Wandlern (76), wobei die Wandler Mittelpunkte aufweisen, die durch einen ersten Abstand S beabstandet sind, und wobei jeder der mehreren Wandler in zusammenwirkender Weise mit zumindest zwei der mehreren der Düsen verknüpft ist;

   einer Einrichtung (14, 38, 44) zum Bewegen des Druckkopfes über das Aufzeichnungsmedium, um darauf flüssige Tinte an Positionen abzuscheiden, die durch einen Abstand zwischen benachbarten Tröpfchen in einer Abtastrichtung des Druckkopfes getrennt sind, der von einem Kontroller (21) als eine Funktion des ersten Abstandes S geteilt durch die Anzahl der Düsen, die in zusammenwirkender Weise mit jedem der mehreren Wandler verknüpft sind, gewählt ist.

2. Die Druckervorrichtung nach Anspruch 1, wobei der Druckkopf ein Wandlerelement (77) mit mehreren Wandlern (76) umfasst; wobei der Druckkopf ein Tintenrichtungselement (78) einschließlich der mehreren Düsen (74) umfasst, wobei das Tintenrichtungselement im Eingriff mit dem Wandlerelement und zu diesem ausgerichtet ist; wobei die mehreren Düsen eine lineare Düsenanordnung umfassen; und wobei die Einrichtung zum Bewegen eine Einrichtung zur Bewegung der linearen Düsenanordnen über das Aufzeichnungsmedium in einer Richtung (24), die im Wesentlichen senkrecht zu

der linearen Düsenanordnung steht, aufweist.

3. Die Druckervorrichtung nach Anspruch 2, wobei das Tintenrichtungselement mehrere Tintenleitungen (104) umfasst, wobei jede der Tintenleitungen mit zumindest zwei der beabstandeten Düsen (74A, 74B) gekoppelt ist; und wobei vorzugsweise jede der Tintenleitungen (104) zumindest zwei Zweige (107A, 107B) aufweist, wobei die zumindest zwei Zweige eine der Tintenleitungen (104) mit zumindest zwei der Düsen (74A, 74B) verbinden.

4. Die Druckervorrichtung nach Anspruch 2 oder 3, wobei die mehreren Wandler eine lineare Anordnung aus thermischen Wandlern (76) umfassen, wobei jeder der thermischen Wandler eine thermische Energie erzeugt; und wobei das Tintenrichtungselement eine Siliziumstruktur aufweist, und wobei die Anordnung aus Tintenleitungen und die Zweige durch einen Ätzprozess definiert sind.

5. Die Druckervorrichtung nach Anspruch 2, wobei das Tintenrichtungselement mehrere Tintenleitungen (100A, 100B) aufweist, wobei jede der mehreren Tintenleitungen mit einer der beabstandeten Düsen (74A, 74B) verbunden ist.

6. Die Druckervorrichtung nach einem der Ansprüche 3 bis 5, wobei das Tintenrichtungselement mehrere Zufuhrkanäle (94) aufweist, wobei jeder der Zufuhrkanäle funktionsmäßig zumindest mit einer der mehreren Tintenleitungen (100A, 100B, 104) verbunden ist; und wobei das Wandlerelement (77) mehrere Grübchenstrukturen (98) umfasst, wobei jede der Grübchenstrukturen zu einem der Zufuhrkanäle und zu zumindest einer der mehreren Tintenleitungen (100A, 100B, 104) zum Zuführen von Tinte zu den Düsen angeordnet ist.

7. Die Druckervorrichtung nach Anspruch 1, die ferner den Kontroller (21) umfasst, der mit der Bewegungseinrichtung verbunden ist, und die Bewegungseinrichtung so steuert, um es dem Druckkopf zu ermöglichen, Tintentropfen an ersten Positionen und an zweiten Positionen, die seitlich von den ersten Positionen durch einen Druckabstand beabstandet sind, der im Wesentlichen gleich im Abstand zwischen den Mittelpunkten benachbarter Düsen der mehreren Düsen ist, abzuscheiden.

8. Die Druckervorrichtung nach Anspruch 1, wobei die mehreren Düsen ein versetzt angeordnetes Düsenarray (142) aufweisen, wobei jede der mehreren Düsen abwechselnd an gegenüberliegenden Seiten einer geraden Linie (146) positioniert ist.

9. Verfahren zum Drucken hochaufgelöster Bilder auf einem Aufzeichnungsmedium (26) mit einem Flüssigtinten-Druckkopf (20) mit Wandlern (76), die Tintentröpfchen auf ein Aufzeichnungsmedium auswerfen, wobei die Wandler Mittelpunkte aufweisen, die durch einen Abstand S beabstandet sind, wobei jeder der mehreren Wandlern funktionsmäßig mit zumindest zwei von mehreren Düsen verknüpft ist, mit:

gleichzeitiges Abscheiden einer ersten Vielzahl von Tintentröpfchen (80) durch die Energiebeaufschlagung eines ersten Wandlers; und

gleichzeitiges Abscheiden einer zweiten Vielzahl von Tintentröpfchen (80), die von benachbarten Tintentröpfchen der ersten Vielzahl in einer Richtung des Abtastens des Druckkopfes durch einen Abstand getrennt sind, der als eine Funktion des ersten Abstandes geteilt durch die Anzahl der Düsen, die funktionsmäßiger Weise mit jedem der mehreren Wandler verknüpft sind, gewählt ist.

10. Das Verfahren nach Anspruch 9, wobei der zweite Abscheideschritt umfasst:

gleichzeitiges Abscheiden der zweiten Vielzahl von Tintentröpfchen durch Energiebeaufschlagung eines zweiten Wandlers; und wobei der erste Abscheideschritt umfasst: Abscheiden der ersten Vielzahl von Tintentröpfchen mit einem abtastenden Druckkopf mit einem Tintenrichtungselement mit mehreren Tintenleitungen, die mit einem Array beabstandeter Düsen gekoppelt sind, und einem Wandlerelement mit einem Array an Wandlern, wobei das Wandlerelement in das Tintenrichtungselement eingreift und zu diesem ausgerichtet ist, derart, dass jeder der Wandler im Wesentlichen zu zumindest einem der mehreren Tintenleitungen ausgerichtet ist.

11. Das Verfahren nach Anspruch 9 oder 10, das ferner umfasst: Steuern des Druckkopfes, um die erste Vielzahl von Tintentröpfchen an ersten Positionen abzuscheiden und um die zweite Vielzahl von Tintentröpfchen an zweiten Positionen abzuscheiden, die seitlich von den ersten Positionen in der Abtastrichtung um einen Abstand getrennt sind, der im Wesentlichen gleich dem Abstand zwischen benachbarten Düsen in dem Düsenarray ist.

Revendications

1. Machine à imprimer (10) dans laquelle de l'encre liquide est déposée sur un support d'enregistrement (26) pour y produire des images à haute résolution, comprenant :

une tête d'impression (20) comprenant une pluralité de buses (74) et une pluralité de transducteurs (76), les transducteurs comportant leurs centres espacés d'une première distance S, chacun parmi ladite pluralité de transducteurs étant coopérativement associé à au moins deux de ladite pluralité de buses ; et

un moyen (14, 38, 44) destiné à déplacer ladite tête d'impression à travers le support d'enregistrement pour y déposer de l'encre liquide à des emplacements séparés par une distance entre les gouttelettes adjacentes dans une direction de balayage de la tête d'impression sélectionnée par un contrôleur (21) comme fonction de la première distance S, divisée par le nombre de buses coopérativement associées à chacun parmi ladite pluralité de transducteurs.

2. Machine à imprimer selon la revendication 1, dans laquelle ladite tête d'impression comprend un élément transducteur (77) comprenant ladite pluralité de transducteurs (76) ; dans laquelle ladite tête d'impression comporte un élément de direction d'encre (78) comprenant ladite pluralité de buses (74), ledit élément de direction d'encre aligné et accordé avec ledit élément transducteur ; dans laquelle ladite pluralité de buses comporte une matrice linéaire de buses ; et dans laquelle ledit moyen de déplacement comporte un moyen destiné à déplacer ladite matrice linéaire de buses à travers ledit support d'enregistrement dans une direction (24) sensiblement transversale à ladite matrice linéaire de buses.

3. Machine à imprimer selon la revendication 2, dans laquelle ledit élément de direction d'encre comporte une pluralité de conduits d'encre (104), chacun desdits conduits d'encre étant couplé au moins à deux desdites buses espacées (74A, 74B) ; et de préférence dans laquelle chacun desdits conduits d'encre (104) comprend au moins deux dérivations (107A, 107B), lesdites au moins deux dérivations connectant l'un desdits conduits d'encre (104) à au moins deux desdites buses (74A, 74B).

4. Machine à imprimer selon les revendications 2 ou 3, dans laquelle ladite pluralité de transducteurs comprend une matrice linéaire de transducteurs thermiques (76), chacun desdits transducteurs thermiques générant une énergie thermique ; et dans laquelle ledit élément de direction d'encre comprend une structure de silicium, ladite matrice de conduits d'encre et lesdites dérivations étant définis par un procédé d'attaque chimique.

5. Machine à imprimer selon la revendication 2, dans laquelle ledit élément de direction d'encre comprend une pluralité de conduits d'encre (100A, 100B), chacun parmi ladite pluralité de conduits d'encre étant couplé à l'une desdites buses espacées (74A, 74B).

6. Machine à imprimer selon les revendications 3 à 5, dans laquelle ledit élément de direction d'encre comprend une pluralité de canaux d'alimentation (94), chacun desdits canaux d'alimentation étant couplé de façon opératoire à au moins un parmi ladite pluralité de conduits d'encre (100A, 100B, 104) ; et dans laquelle ledit élément transducteur (77) comprend une pluralité de structure de perforations (98), chacune desdites structures de perforations étant disposée adjacente à l'un desdits canaux d'alimentation et à au moins l'un parmi ladite pluralité de conduits d'encre (100A, 100B, 104) pour délivrer de l'encre aux buses.

7. Machine à imprimer selon la revendication 1, comprenant en outre un contrôleur (21) couplé audit moyen de déplacement, commandant ledit moyen de déplacement afin de permettre à ladite tête d'impression de déposer des gouttes d'encre à des premiers emplacements et à des deuxièmes emplacements latéralement espacés des premiers emplacements d'une distance sensiblement égale à la distance entre les centres des buses adjacentes de ladite pluralité de buses.

8. Machine à imprimer selon la revendication 1, dans laquelle ladite pluralité de buses comprend une matrice en quinconce de buses (142), chacune parmi ladite pluralité de buses étant placée alternativement sur les côtés opposés d'une ligne droite (146).

9. Procédé d'impression d'images à haute résolution sur un support d'enregistrement (26) avec une tête d'impression à encre liquide (20) comportant des transducteurs (76) éjectant des gouttelettes d'encre sur un support d'enregistrement, lesdits transducteurs comportant des centres espacés d'une distance S, chacun parmi ladite pluralité desdits transducteurs étant associé coopérativement au moins à deux parmi une pluralité de buses comprenant les étapes consistant à :

déposer une première pluralité de gouttelettes d'encre (80) simultanément en mettant sous tension un premier transducteur ; et

déposer une deuxième pluralité de gouttelettes d'encre (80) simultanément, espacées des gouttelettes d'encre adjacentes de la première pluralité dans un sens de balayage de la tête d'impression d'une distance sélectionnée en fonction de la première distance S, divisée par le nombre de buses coopérativement associées à chacun parmi ladite pluralité desdits transducteurs.

10. Procédé selon la revendication 9, dans lequel ladite deuxième étape de dépôt comprend le dépôt de la deuxième pluralité de gouttelettes d'encre simultanément en mettant sous tension un deuxième transducteur ; et dans lequel ladite première étape de dépôt comprend le dépôt de la première pluralité de gouttelettes d'encre avec une tête d'impression à balayage comprenant un élément de direction d'encre possédant une pluralité de conduits d'encre couplés à une matrice de buses espacées et un élément transducteur possédant une matrice de transducteurs, l'élément transducteur étant aligné et accordé avec l'élément de direction d'encre de sorte que chacun des transducteurs est sensiblement aligné avec au moins l'un parmi la pluralité de conduits d'encre.

11. Procédé selon les revendications 9 ou 10, comprenant en outre la commande de la tête d'impression pour déposer la première pluralité de gouttelettes d'encre à des premiers emplacements et pour déposer la deuxième pluralité de gouttelettes d'encre à des deuxièmes emplacements espacés latéralement des premiers emplacements dans le sens de balayage d'une distance sensiblement égale à la distance entre les buses adjacentes de la matrice de buses.

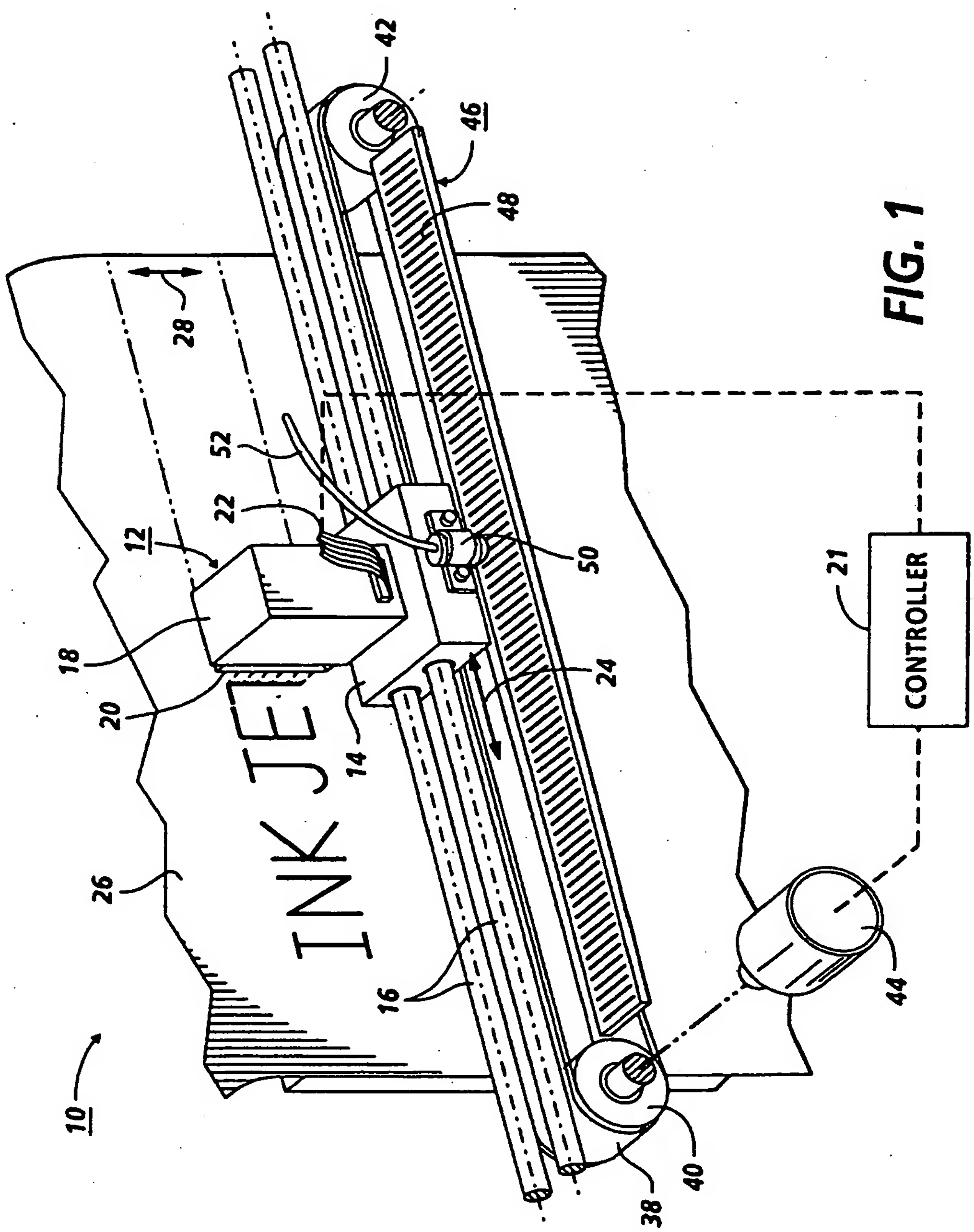
10
12
14
16
18
20
21
22
24
26
28
38
40
42
44
46
48
50
52
INK JET
CONTROLLER

FIG. 1

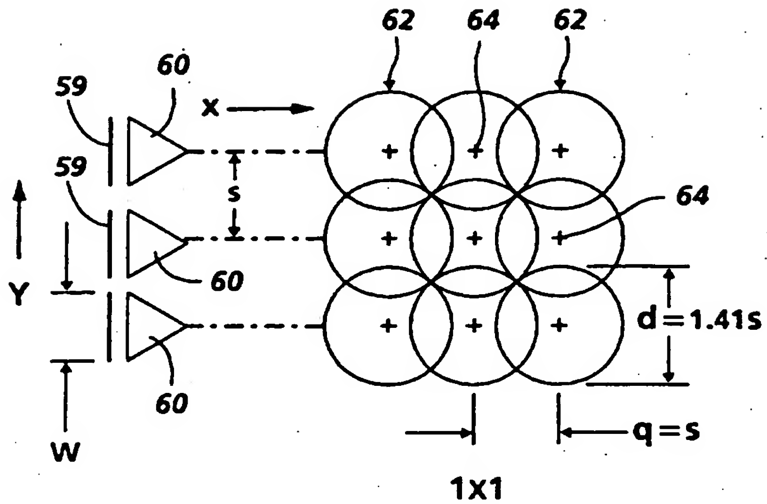
62
64
62
60
59
X
59
64
s
Y
60
d=1.41s
60
W
q=s
1X1

FIG. 2

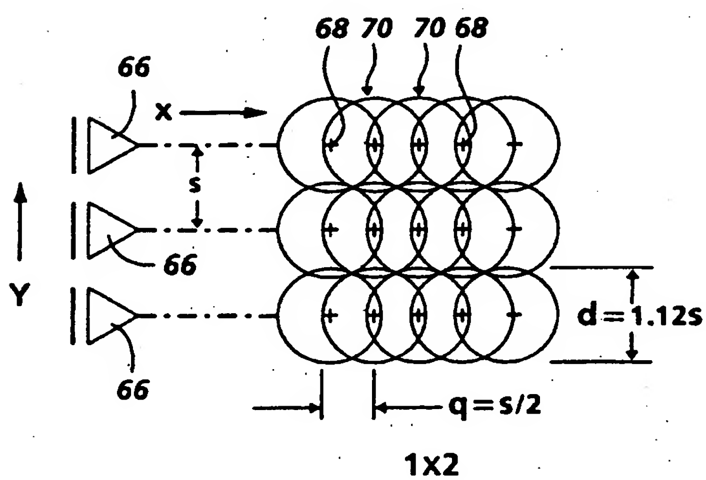
68
70
70
68
66
X
s
66
Y
d=1.12s
66
q=s/2
1x2

FIG. 3

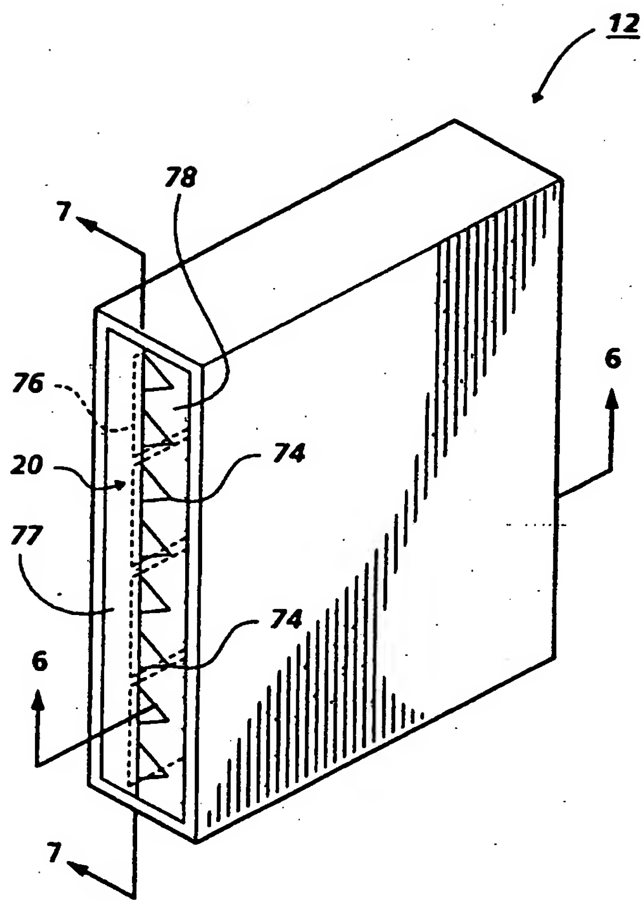

FIG. 4

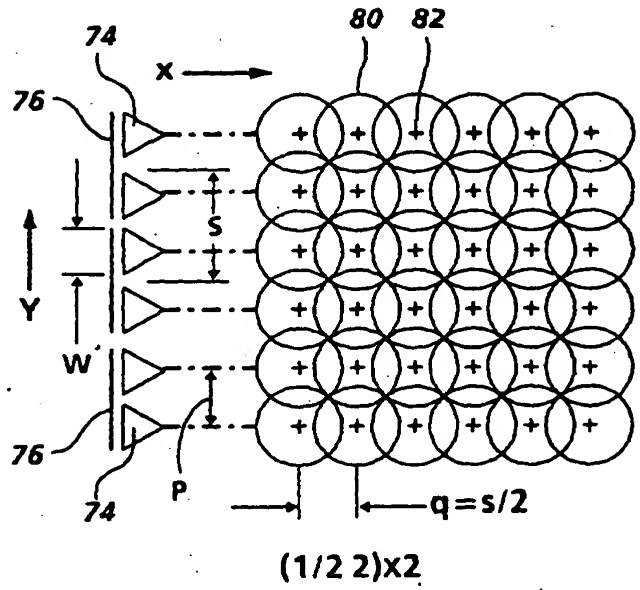

FIG. 5

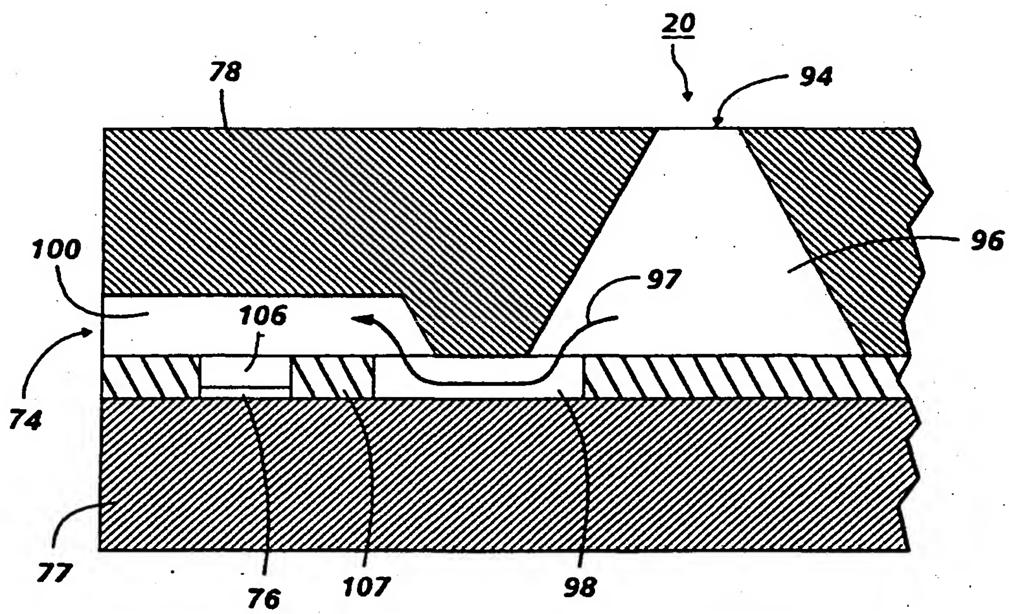

FIG. 6

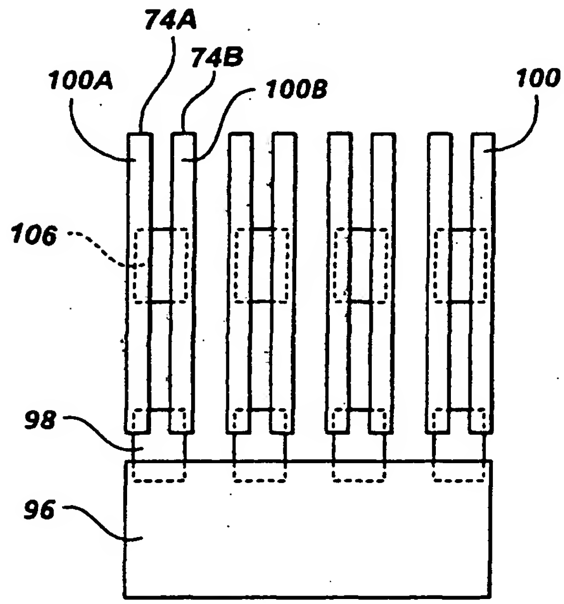

FIG. 7

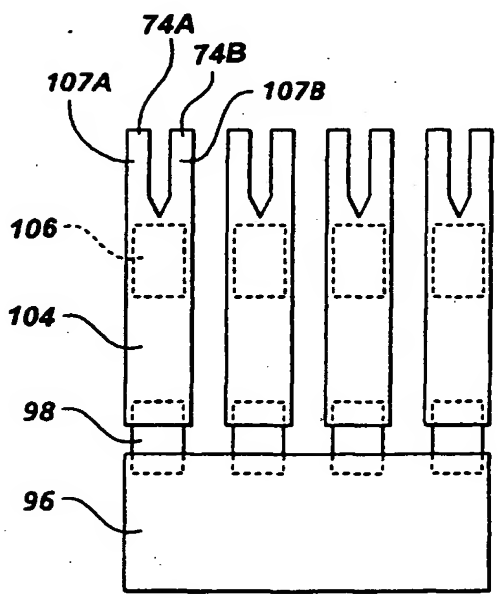

FIG. 8

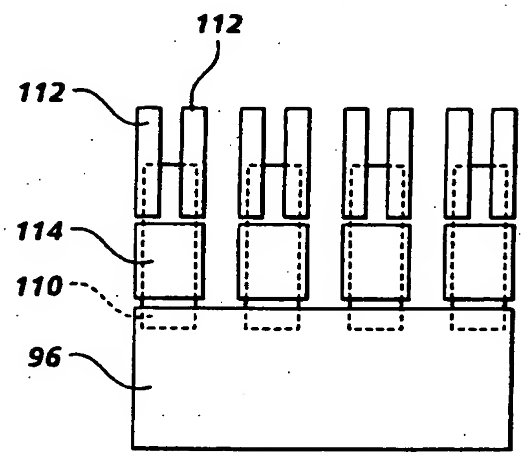

FIG. 9

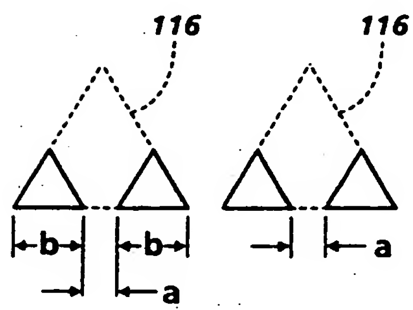

FIG. 10

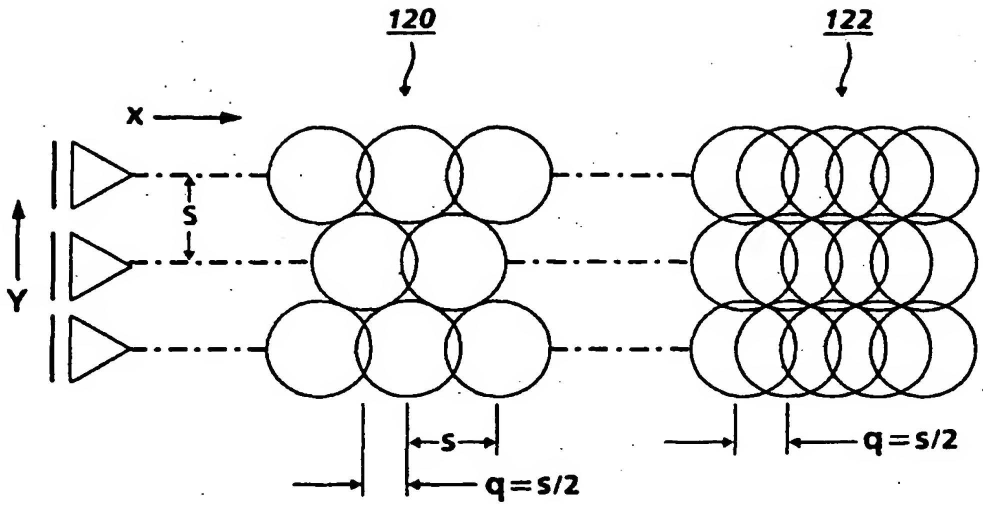

FIG. 11

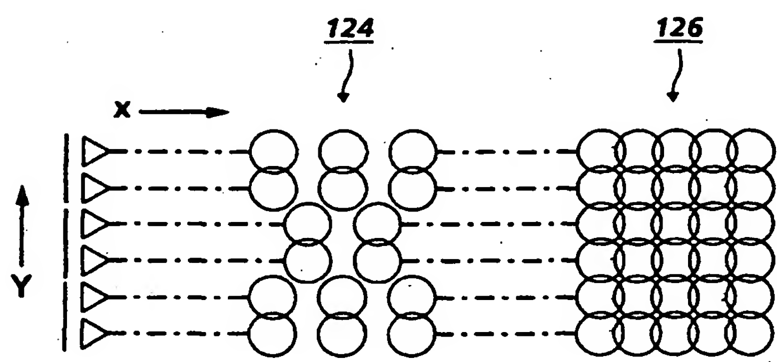

FIG. 12

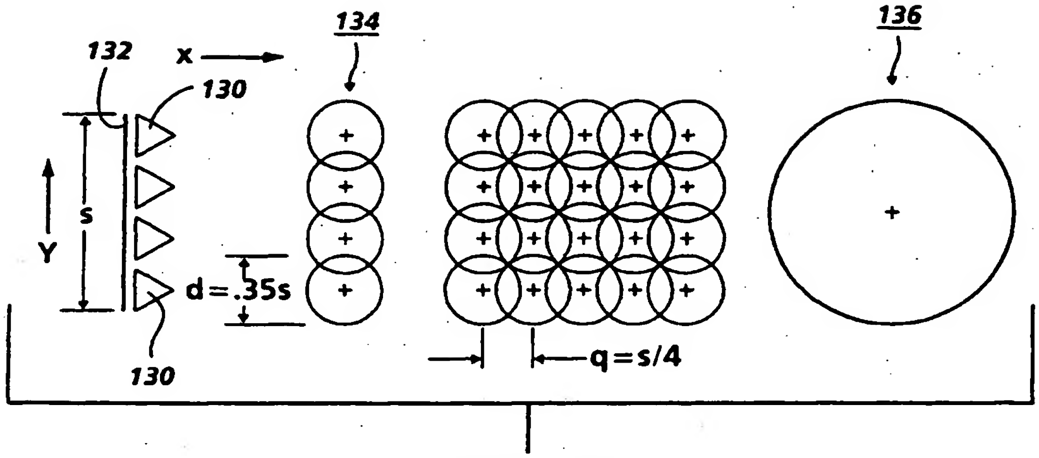

FIG. 13

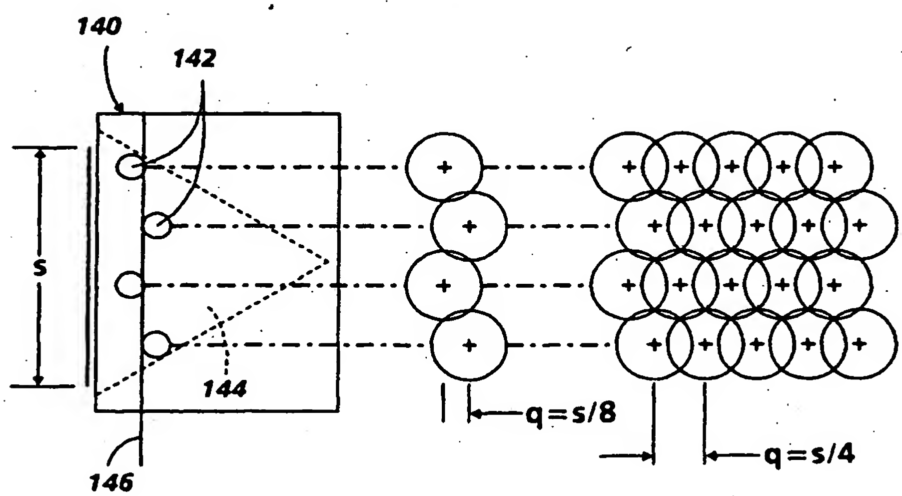

FIG. 14